Diamond AP
User Manual

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Document History

Name	Date	Changes Made

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Description

The Diamond AP is a dual-redundant autopilot system with fault monitoring and automatic fail-over. There are two complete flight control systems (FCS) on the one circuit board. These systems are

- Main
- Standby

Power Distribution

The main and standby systems can be powered independently for greater failure tolerance. If it is inconvenient to provide independent power supplies, the two systems can be powered together by placing a header pin jumper across the main and standby power pins designated by white lines around the 3-pin connect next to the micro-SD card holder.

The following devices are powered by the main system.

- Main microcontroller
- Primary 'automotive grade' gyros and accelerometers
- Backup 'commercial grade' gyros and accelerometers
- Backup magnetometer
- Backup altimeter
- Micro-SD card
- Telemetry and sensor connectors
- RC receiver
- Servo power bus

The following devices are powered by the standby system

- Standby microcontroller
- Gyros, accelerometers, magnetometer
- GPS
- Standby telemetry
- RC receiver
- Servo power bus

Regardless of which system is powered, both the RC receiver and servos will be powered.

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Power supply selection

The autopilot requires 4.5V to 5.5V.

Voltages greater than 5.5V will damage the autopilot!

Some hobbyist BECs labelled as 5V will produce greater than 5.5V, so always check with a digital multi-meter before connecting.

The servos can operate on up to 6.5V max. It is safe to connect the servo power pins to a 6V source.

The power supply should provide smooth and clean power. A noisy power supply can cause erroneous sensor readings (which can cause the artificial horizon and altimeter to become inaccurate) and can greatly increase GPS time-to-fix. If these issues are observed, placing a ferrite ring around the power supply leads or using a different power supply is recommended.

Remote Control (PWM) Input

There are twelve pins for PWM (pulse width modulation) signals from a remote control receiver. The main system receives all twelve PWM signals. The standby system receives only the first six signals.

Servo (PWM) Output

There are twelve servo channels. In normal operation, the main system is responsible for the signals on all 12 channels. The main system generates PWM using a servo driver.

The standby system monitors both the servo driver and the main system. In normal circumstances, the standby system is in *monitoring mode*. If a failure of the servo driver is detected, the standby system will driver the servos instead. This mode is called *driving mode*. If a failure of the main system is detected, the standby system will become responsible for all flight control. This is called *fail-over mode*.

The standby system provides monitoring and redundancy for PWM channels 1 to 6 only. Therefore it is strongly recommended to assign all flight controls to the first six channels.

The PWM signal voltage level will vary between 3.3V and 5V. The servos must operate at both levels.

Mounting To Airframe

The autopilot must be installed in line with the axis of the aircraft and as close to the centre of gravity as reasonably possible. With the aircraft held straight and level, the orientation shown on the artificial horizon should be straight and level. If the error on pitch or roll axis is outside greater than

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+/- 3 degrees, the autopilot should be recalibrated on a level surface and the mounting point should be adjusted.

The autopilot uses MEMs gyroscopes which can be vibration sensitive. It is recommended that the autopilot is installed on anti-vibration mounts. Before flight, run the motor through all RPM ranges while watching the artificial horizon. If the artificial horizon jitters wildly (+/- 5 degrees) or becomes unstable, then further anti-vibration measures are required. This might include balancing propellers and adding anti-vibration mounts to motor mount points.

Telemetry

The telemetry and standby telemetry ports on the autopilot is a UART port that runs at 57600 bits per second. RFD900 radio modems are recommended.

Sensors

The sensor bus is a high speed digital data bus. It is used to connect external sensor modules to the autopilot.

ADC and GPIO

There are four digital general purpose input/output (GPIO) pins and four analog input pins. These pins are programmable and can be used to customise the autopilot.

The analog to digital converter is limited to 3.3V max. Putting more than 3.3V on these pins can damage the autopilot. The GPIO pins are 3.3V nominal and 5V tolerant. Digital output maximum current is 20mA.

Channel Mixing

The autopilot needs to know how to fly the aircraft, and so channel mixing cannot be done using the remote control transmitter. Instead, a mixer program must be created to instruct the autopilot how to mix channels. This means unlimited possibilities for channel mixing. Please refer to the programming manual for more details.

For aircraft that do not require sophisticated channel mixing, the Mixer Generator software tool can greatly simplify the process. It has a simple user interface and generates mixer code based on the setting provided.

Payload Control

The autopilot can be programmed to control a payload. Examples include camera triggers, gimbals and lights.

Available inputs are

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- orientation, position, altitude and speed information
- datalink from GCS (limited to approximately 150 bytes per second)
- GPIO digital ins
- ADC pins
- RC receiver (PWM input)

Available outputs are
- Servos 5 to 12 (servos 1-4 are dedicated for flight control and cannot be overridden)
- datalink to GCS (150 bytes per second max)
- GPIO digital outs

Please refer to the programming manual for more information.

Autopilot Modes

There are seven autopilot modes. Manual, Trainer, PNR and HNA modes require operator input. Loiter, RTB and Waypoints are completely autonomous.

Manual

Manual mode is exactly that. The aircraft will operate just like a normal RC plane.

Trainer

Trainer mode is an anti-crash mode. It allows for full manual control, except it will not allow the aircraft to become inverted or to descend below 120ft.

If the aircraft goes below 120ft, the autopilot will select zero bank and maximum pitch up attitude.

If the bank angle exceeds +/- 90 degrees, the autopilot will apply full aileron to 'kick' the aircraft back and prevent it from going upside down. If the pitch angle exceeds +/- 45 degrees, the autpilot will apply full opposite elevator.

PNR

PNR mode is a stabilised mode. In this mode, the elevator stick becomes a pitch selector and the aileron stick becomes a bank selector. This mode is very easy to fly in. Moving the elevator stick back will cause the aircraft to pitch up and climb. Moving the aileron stick to the side will cause it to roll over and begin to turn. Taking your hands off the controls will cause the aircraft to fly straight and level.

Turns in pitch and roll mode are automatically coordinated and the rudder stick is not used.

Minimum and maximum bank angles are ignored in this mode.

Even though this mode is stabilised and easy to fly in, it still requires constant operator input and attention.

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HNA

In heading & altitude mode, the sticks become ground track and altitude selectors. Using the elevator stick to pitch up will cause the selected altitude to increase and using the aileron stick to roll will change the selected ground track.

This mode is extremely easy to fly in, although it's difficult to know what the selected ground track and altitude actually is without having the GCS in front of you.

Loiter

Loiter will make the aircraft fly in a clockwise circular pattern. When the aircraft is put into loiter mode, the location and altitude of the aircraft are used to set the loiter position and height.

The altitude can be changed with the elevator control stick, just as in H&A mode.

The radius of the loiter circle can be changed by tweaking the loiter radius and correction strength settings in the configuration window.

Waypoints

When waypoints mode is selected, the aircraft will begin to follow the flight plan. If no flight plan has been uploaded, the aircraft will loiter.

When a waypoint is reached, the autopilot checks that the aircraft is at the correct altitude. If so, the next waypoint is selected. Otherwise it will loiter over the waypoint until the selected altitude is reached. At the end of the flight plan, the aircraft will loiter over the last waypoint.

There is no guarantee that the aircraft will fly over each and every waypoint. It uses only the distance travelled to decide if a waypoint has been hit. The reason for this is that sometimes an operator will place waypoints too close together. If this is the case and the aircraft can't turn soon enough to actually over-fly the next waypoint, then it will just skip to the next one.

Alarms and Fail-safes

The autopilot monitors various parameters and activates alarms if something goes wrong. You can set an action for the autopilot to carry out when an alarm is activated. For example, if the RC receiver loses signal for more than 1.5 seconds, the 'remote control signal lost' alarm is activated. You can set the action for this alarm to 'Return to base'. The autopilot will then fly the aircraft back if it loses RC signal.

What if the GPS drops out while the aircraft is returning to base? The aircraft will dead-reckon for 20 seconds and then the 'No GPS Lock' alarm will activate. If you have set the 'No GPS Lock' action to fixed bank loiter, the aircraft will bank 10 degrees and maintain altitude. If the alarm action is set to None the aircraft will continue to dead-reckon until the GPS gets a position fix. Whilst dead-reckoning, the geofence alarm is disabled.

As you can see, the alarms are a powerful and complex feature of the autopilot. The autopilot has

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some built in intelligence that determines the most sensible action to take if multiple alarms are activated at the same time. Your autopilot should never do anything silly or unexpected, but the alarm actions you chose will seriously affect the way your aircraft behaves when things go wrong.

The following settings are recommended.

Boundary collision – Return to base
Low Power - None.
No GPS Lock - Fixed bank loiter.
Remote control signal lost - Return to base
Datalink lost - Manual control

If you lose sight of your plane, TURN OFF THE RC TRANSMITTER.
If the aircraft is beyond line of sight and the datalink drops out, the aircraft will switch to manual and crash. If the aircraft has no RC signal and no datalink, then it will return home. When the aircraft returns to line of sight, you may switch on your RC transmitter. The plane will then go into manual and you can land it safely.

Home Position

The home position is the coordinates that the aircraft will return to in RTB mode.

The home position is set automatically when the GPS gets a 3D lock for the first time after power on.

Altitudes

Two different altitudes are used:

- Pressure altitude
- Altitude above ground level (AGL)

Pressure altitude is calculated from ambient pressure using the altimeter setting (default is 1013.25 millibars).

When the GPS first gets a 3D lock, the current pressure altitude is stored and used as the ground reference altitude. AGL then becomes pressure altitude minus ground reference altitude.

The autopilot uses AGL for autonomous modes such as return to base and waypoints.

The altimeter setting and reference altitude can be changed using the ground control station. The altitude settings should be checked over before take-off and should not be changed at all during autonomous flight.

Do not change altitude settings during autonomous flight.

AHRS Calibration

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Measurements from the sensors are filtered and fused together to form an attitude and heading reference system (AHRS) so the autopilot can sense the orientation of the aircraft. For the autopilot to fly well, it must be able to estimate orientation very accurately and that means the sensors must be calibrated.

The sensors that require calibration are the magnetometers and accelerometers. The magnetometers are corrected for bias and scale errors, and the accelerometers are corrected for bias only. The other sensors do not require calibration.

Calibration is easiest before the autopilot is installed in the aircraft.

To begin, open FiretailGCS and connect to your flight controller. Open the configuration window and select the 'AHRS' tab on the left. Click the 'Calibrate' button.

Magnetometer Calibration

The X-Y, X-Z and Y-Z graphs in the AHRS calibration window are scatter plots that represent magnetometer readings. For the magnetometers to be calibrated, you'll need to collect as many samples from the magnetometers as possible. A good number of samples is about 2500 - 3000, and this could take up to 10mins. In this time, you'll have to move your flight controller around through as many orientations as possible. The basic idea is to try and draw three circles on each of these scatter plots.

To begin collecting magnetometer samples, click the 'Sample Magnetometers' toggle button.

Once you've got enough samples, click 'Sample Magnetometers' again to stop.

Any unusual spikes or stray samples on your plots will affect the result of the calibration. Excess samples can be removed by increasing the amount of sample culling. Once you are happy with the magnetometer samples, you're right to go on to accelerometer calibration.

Accelerometer Calibration

The accelerometers are calibrated for bias only. When the autopilot is held perfectly level, the Z axis (up and down accelerometer) should read 1g and the X and Y axes should read 0g. Accelerometers nearly always read some other value that is close, but slight offset from what it should be. This is bias error.

Accelerometer bias calibration is simple, but requires a surface that is perfectly level. Once you've got magnetometer samples and the flight controller is sitting on a level surface, click the 'Calibrate' button.

Checking The Calibration

After clicking 'Calibrate' the X-Y, X-Z and Y-Z scatter plots should go from being offset and oval shaped to being centred on the graph and nicely circular. If this the case, click 'Ok'. You may now upload the new calibration data. If not, try culling more samples. If that still doesn't help you might have to click 'Reset' and start from scratch.

After uploading the calibration data, have a look in the flight display. The attitude indicator should

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be spot on now. After calibration it will often be within +/- 1 degree.

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